**Appendix 1**

# Gas Bill Estimation Study

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The Policy Program performed a study of estimation methods. Before proceeding to discuss that study, Staff notes that no estimation method is going to be flawless. Furthermore, there is no need for such methods to be flawless. Eventually, each customer's meter is going to be read. At that point, the sum of usage since the previous actual meter reading will be known, placing a limit on how much customers can be over billed or under billed in the long run. To the extent to which individual customers are over billed due to inaccurate estimation of usage, most if not all of the excess revenues flowing to the utility will be credited against purchased gas costs, leading to a decrease in the purchased gas cost adjustment factor in later months. Hence, while fairness to individual customers dictates that we pay close attention to the issue of estimation accuracy, we should not exaggerate the impact and importance of such accuracy. There should be some recognition of the costs and benefits of obtaining marginal improvements in accuracy. Thus, the Policy Program's study concentrated on identifying utility methods with significant problems.

To perform the study, the Policy Program chose to use samples of actual billing data and measure the extent to which estimates deviated from actual metered usage. The Policy Program decided to limit the scope of this study to the larger gas utilities: Ameren, Central Illinois Light Company, Illinois Power Company, Northern Illinois Gas Company, and Peoples Gas Light and Coke Company. Each of these companies was asked through a data request to provide a detailed description of their estimation methodologies and a sample of customer usage data with which the Policy Program would measure the accuracy of these methods.

The data samples were to include at least two years of billing records for at least 200 customers. The Policy Program would write computer programs to essentially replicate the utilities' estimation methods and to compare the estimates to the "actual" usage derived through meter reads.[1] The difference between the estimate and the actual usage for any given customer and billing period is the error. To judge the accuracy of the various estimation methods, the Policy Program attempted to characterize the magnitude and direction (plus or minus) of the errors generated by these methods. In addition to examining the accuracy of the utilities' methods, the Policy Program created several straw-man methods for comparison purposes.

The Policy Program was largely successful in carrying out the study. However, several problems arose in the course of the Policy Program's investigation. For example, some of the utilities do not retain (beyond the estimation month) all the information that is used to perform estimations. In these cases, involving Ameren and NI-Gas, the Policy Program was unable to replicate the utilities' methods. In NI-Gas' case, company reports are available for a significant historical period, which purport to show the accuracy of the utility's method. In Ameren's case, while similar reports are generated on a daily basis, the company has routinely discarded them; none are available showing the accuracy of the company's method during any heating season. From this point forward, Ameren will be retaining two of these reports each month and providing them to the Staff for review at least through the next heating season. Notwithstanding such problems, the Policy Program believes that the utilities have been cooperative in providing the data and in explaining the details of their methods.

[1] Of course, the validity of this approach relies on meter reads themselves being accurate, a separate line of inquiry considered elsewhere within this report.

For purposes of this report, gas consumption by a typical residential consumer can be thought of as having two basic components: a base-use component and a weather-sensitive component. The base-use component would relate to uses that do not depend much if at all on the current state of the weather: for example, gas stoves, pilot lights on household appliances, gas water heaters (especially in a heated basement), etc. The weather-sensitive component relates to the use of gas for maintaining comfortable household temperatures during the heating season: primarily the gas furnace or boiler.

Many utilities assume that usage is a simple function of the form:

$$U_t = a \times Days_t + b \times HDD_t + e_t \times Days_t$$

or

$$UPD_t = a + b \times HDDPD_t + e_t$$

where

| | |
|---|---|
| $U_t$ | is usage in time span t, |
| $UPD_t$ | is usage per day in time span t ($UPD_t=U_t/Days_t$) |
| $a$ | is the base-use component in units of usage per day |
| $b$ | is the weather sensitive component in units of usage per heating degree day |
| $Days_t$ | is the number of days in time span t. |
| $HDD_t$ | is the number of heating degree days in time span t. Heating degree days are equal to |

$$\sum_{\forall \mathrm{days} \in \mathrm{t}} \mathrm{Max}(65 - \mathrm{Temp}_{\mathrm{days}}, 0)$$

That is, $HDD_t$ is the sum over all the days in time span t, of 65 degrees F. minus the average temperature for the day, or zero, whichever is greater. Average temperatures above 65 degrees F. tend to have little or no effect on space heating activities. Hence, weather data providers typically report HDD around a base temperature of 65 degrees F.

$HDDPD_t$ is the number of heating degree days per day in time span t ($HDDPD_t = HDD_t / Days_t$).

$e_t$ represents the random component of usage per day during time span t.

The validity of such a simple two-equation model is born out through observation. For instance, relying on the sample data provided by Illinois Power, including 199 customers, each customer's meter read usage per day was regressed on heating degree days per day and the parameters a and b were estimated. The median R-squared (a measure of goodness of fit) was 0.97 (with 1 being the theoretical highest level).[2] The same analysis on a NI-Gas data sample resulted in a median R-squared of 0.96.[3] The same analysis on a CILCO data sample resulted in a median R-squared of 0.98.[4]

The parameters of such an equation also may be estimated using more simple algebraic approaches. An example of a simple algebraic approach would be as follows: First, identify a base-use per day factor by observing recent summer period usage data for a customer. Second, use that base-use factor to compute base usage for the most recent non-summer period. Third, subtract the base usage off of total usage during some non-summer period, and divide the result by the total heating degree days during that non-summer period to compute a temperature sensitive usage component. Fourth, use (a) the base-use factor and (b) the temperature-sensitive use factor, derived from

[2] For IP, the median value for the a parameter (base use per day) was 0.49 therms per day and the median value for the b parameter (the slope) was 0.13 therms per HDD per day.
[3] For NI-Gas, the median value for the a parameter (base use per day) was 0.58 therms per day and the median value for the b parameter (the slope) was 0.17 therms per HDD per day.

steps one through three, to estimate usage in some other time period, t: This is the type of approach used by Peoples Gas Light and Coke Company.

$$U_t = a \times Days_t + b \times HDD_t$$

where

$$a = \frac{U_{summer}}{Days_{summer}}$$

$$b = \frac{[U_{summer} - (a \times Days_{non-summer})]}{HDD_{non-summer}}$$

As a benchmark for comparing the various utility methods, the Policy Program utilized several methods for estimating the parameters a and b:

- Method 2: Use most recent summer period to find a; and most recent non-summer month to find b.
- Method 3: Use most recent summer period to find a; and same month last year to find b.
- Method 4: Use most recent summer period to find a; and last 12 months to find b.
- Method 5: Use whatever customer data is available preceding the estimation date to find a and b simultaneously by minimizing the sum of squared errors (ordinary least squares regression). Since the data sample had only two years of data, early points in the data sample would have fewer observations available for the regression than the more recent points. Within a billing system that continuously retained two years worth of data, such a limitation would not exist, except for relatively new customers. Furthermore, one might argue that older information may be less valid than newer information. However, no efforts were made to find the optimum number of observations to utilize with the regression approach.

Other estimation approaches can be used that do not rely on an explicit accounting for base use and temperature-sensitive use components. The IP and Ameren methods, for instance, rely on the ratio of actual metered usage by large groups

[4] For CILCO, the median value for the a parameter (base use per day) was 0.44 therms per day and the

of similarly-situated customers in two different time periods and assume the same ratio applies to customers for whom estimates are being computed.

Thus, for a customer, i, with known usage in time period t-1, but unknown usage in time period t (requiring estimation), the estimate would be as follows:

$$Estimated\ u_t^i = u_{t-1}^i \times \frac{U_t^{group}}{U_{t-1}^{group}}$$

NI-Gas uses a kind of hybrid model. First, NI-Gas computes customer-specific base-load and HDD-sensitive parameters and the resulting estimate based on the number of days and HDD in the current billing period. Then, NI-Gas modifies the resulting estimate with a factor derived through analysis of a group of similarly-situated customers (specifically by multiplying the customer-specific estimate by the ratio of actual to estimated usage of those similarly situated customers). The theoretical advantage of such a hybrid approach is that it takes into account customer-specific idiosyncrasies as well as the myriad of factors that might drive the average customer's usage to change from one time period to the next.

CILCO's approach is unique. It is similar to the IP approach and the Staff's straw man models, in the sense that customer-specific parameters are computed. However, CILCO ignores the base-use component and also includes a ratio of "normal" heating degree days in the estimation of their slope parameter. On their face, the lack of a base-use component and the introduction of normal heating degree days both appeared to be innovations without theoretical merit. The use of normal heating degree days is particularly perplexing and has never been adequately explained by CILCO. Normal degree days are useful when preparing a long-range forecast for a period of what one

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median value for the b parameter (the slope) was 0.14 therms per HDD per day.

expects to be “normal” weather. However, in the context of preparing an estimate of usage during a recently concluded period for which one has actual HDD data, normal heating degree days are irrelevant.

The table, below, shows how the various methods compare in terms of accuracy. Within this table, there are five threshold levels of error (plus or minus 10%, 15%, 20%, 30%, and 50%). Using the data samples of actual billing histories from the various utilities, and the various estimation methods, discussed above, the table shows the percentage of observed errors that were within each of these five threshold levels. The results for Staff’s straw man models are shown as ranges because they were employed in each of the data samples, while the utility models were employed just with that utilities data sample.

| Error Tolerance Levels | Illinois Power Method | Peoples Method | NI-Gas Method | CILCO Methods | | | Staff's Straw Man Methods | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year-ago Method | Month-ago Method | Year-ago, if data available, else Month-ago Method | Method 2: Month-Ago | Method 3: Year-Ago | Method 4: Last 12 Months | Method 5: Regression with remaining data available in sample |
| **+/- 10%** | 32% | 31% | 55% | 32% | 10% | 20% | 37-44% | 34-46% | 36-50% | 35-47% |
| **+/- 15%** | 43% | 44% | 69% | 44% | 14% | 28% | 49-58% | 48-61% | 49-64% | 47-60% |
| **+/- 20%** | 51% | 53% | 78% | 56% | 18% | 36% | 57-66% | 58-71% | 59-74% | 56-69% |
| **+/- 30%** | 63% | 65% | 87% | 73% | 28% | 48% | 69-77% | 69-82% | 71-85% | 68-81% |
| **+/- 50%** | 79% | 78% | 94% | 87% | 55% | 71% | 83-89% | 83-92% | 84-94% | 83-91% |

As predicted by Staff, the CILCO method turns out to be the least accurate of all the methods examined, and it results in biased estimates under certain circumstances, as well. The bias occurs when the ratio of normal heating degrees employed by the model deviates significantly from zero (as it does through much of the heating season).

In contrast, the other utility methods appear both theoretically sound and result in what Staff considers to be an acceptable degree of accuracy. Therefore, the Policy Program does not recommend immediate action by any of the utilities, with the exception of CILCO. Of course, it is unrealistic to expect that CILCO's billing system could be replaced or overhauled "immediately." Hence, until its usage estimation routines are satisfactorily remedied, CILCO should take steps to avoid estimating bills. That is, CILCO should read as many meters as possible. Meanwhile, CILCO should immediately begin the process of rectifying its estimation procedure. In the Policy Program's opinion, the other utilities should examine ways to improve upon their methods in the normal course of business (for example, as billing systems are replaced, or as time permits within regular work schedules).

The most accurate method appears to be one employed by Northern Illinois Gas Company ("NI-Gas"). The Policy Program cautions, however, that this conclusion is preliminary. That company was not able to supply all the data required by Staff to perform an independent assessment of estimation accuracy. Instead, NI-Gas supplied its own accuracy reports, which are generated on a daily basis and retained. Based on these reports, the NI-Gas method appears to outperform the other utilities' methods, as well as the straw man methods developed by the Policy Program for purposes of this study.

The Staff encourages utilities to pursue ways to fine-tune their usage estimation methods. The Staff may also consider this an ongoing project, subject to its own internal resource constraints. Several avenues for further study have occurred to the Policy Program in the course of its investigation:

- Studying the improvement associated with NI-Gas' second step, i.e., where a group of similarly-situated customers' actual usage divided by estimated usage in the current period is multiplied by the individual customer's estimate.

- For the regression approach, studying the impact of using more (but older) data points.  For instance, do regressions based on 24 month samples perform better or worse than those based on 12 month samples.
- Studying the factors that seem to result in one method outperforming another method and developing a hierarchy of which methods to use first based on the type of customer, the time of year, the availability of data, and other factors identified to be important in this regard.